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Fault Diagnosis of Rural Power Network Based on GIS Platform and Rough Set

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Abstract
By analyzing the rural power network topology of GIS platform, to obtain a simplify structure of relay protection and circuit-breaker as key equipment, and then use rough set fault diagnosis algorithm designed rural power network fault diagnosis module based on GIS platform, for quickly determine the fault point position of rural power network, given troubleshooting solutions. The problem of spatial search speed bottleneck in GIS platform is solved by using the rough set fault diagnosis algorithm. The practical engineering application shows that the search speed and accuracy are improved. Combined with the existing 4G communication mode, the circuit-breaker states are quickly detected. Finally, the system automatically generates the operation order of the power network, which can guide the staff to quickly eliminate the fault, shorten the power outage time and improve the reliability of power supply.
Key words: ROUGH SET, RURAL POWER NETWORK, FAULT DIAGNOSIS

1. Introduction

At present, the main power network fault location is based on the scheduling model which is lack of the necessary simulation, and does not provide the line load transfer scheme, and the control of the line is based on the natural on/off power. As the circuit-breaker control state and line relationship is not quantified, the problem of solving problems is lack of relevant mathematical model, so that the efficiency of fault diagnosis algorithm is not high, and there is no information about the structure of the overhead line, and the structure of the power network is lack of vi-

sual image [1]. Based on the GIS platform which can provide the topology of the actual line, the power network diagnosis system solves the above problems. A scene simulation environment based on GIS platform is provided about logical connection between the tower, circuit-breaker, and overhead line and using of road, construction and other map information to make the fault point positioning more accurate and intuitive.

Secondly, in order to improve the accuracy and the rapidity of the fault diagnosis, many native and foreign scholars have brought forward expert system, artificial neural network, fuzzy Petri net and genetic algorithm and so on [2-4]. Most of these methods can gain a satisfying result for the accurate and complete signals that are send to control center. However the signals are uploaded incompletely in practical fault diagnosis, such as the misinformation took place from relay protection or circuit-breaker, and signals are changed or lost because of the communication set malfunction. In allusion to the fault diagnosis of distribution network when it transmits incomplete information, we need to consider an inexact reasoning method for the information's Fault-Tolerant capacity. Rough set theory is a new mathematical tool to deal with the fuzzy and uncertain information [5-6], and it has obviously strong Fault-Tolerant capacity. Due to rough set theory can effectively handle the imprecise problems without any ancestor information except the data set itself, and in the precondition of keeping out the key information, it can reduce the data to the minimum reduction. The inherent redundancy in the alarm information is exposed, and a new approach has been explored for handling the imperfection alarm information. For this reason, a new distribution network fault diagnosis approach to deal with the imperfect alarm signals that caused by malfunction or failing operation of relay protection and circuit-breaker, error in the communication equipment is proposed. First, the signals of relay protection and circuit-breaker are looked as condition attributes and a decision table is constructed by considering every possible fault. And then, the program conducts attri- bute reduction and value reduction, finally the diagnosis rule is found. Accordingly, the fault diagnosis of distribution line is carried out with the method.

In addition, communication system is an important part of the distribution automation system. At present, the communication mode adopts optical fiber mostly. Optical fiber communication has the characteristics of high transmission rate, high reliability and low interference. However, due to the attenuation of the signal in the transmission process, every other line needs to add a repeater to enhance the signal, which makes the cost increase. Taking into account the rural power network construction cost, installation, maintenance, reliability, communication speed, coverage area and other factors, this paper presents the 4G LTE network is applied to the feeder automation communication system. 4G LTE is a kind of high speed wireless communication network [7]. It has the advantages of low cost, simple installation, convenient maintenance, high reliability, high communication speed and wide coverage area.

In this paper, from the point of view of engineering application, the simplified topology of the relay protection and circuit-breaker as the key equipment in the rural power network is established based on the GIS platform. Then, using rough set fault diagnosis algorithm, can quickly and accurately determine the location of the fault point, and automatically generate the operation order of the scene of the power network. In the engineering application, the fast detection of circuit-breaker state is realized by combining the existing 4G communication mode.

2. Simplified topology of rural power network based on GIS platform

Because the multi power supply circuit has the characteristics of complex structure, multi loop and difficult control, so the research on fault characteristics of power network based on grid topology structure [8]. As the fault information comes from the position of the circuit-breaker, the connection relationship and the electrical quantity, the structural fault analysis is different from the power grid analysis of other electric power application software. The characteristic analysis (theoretical loss calculation, flow calculation etc.) of the general power grid focus on the connection between the connections of primary devices. The Power network fault diagnosis is an analysis of the local power network, which only analyzes the connection between the electrical equipment and the power network in the fault area. At the same time, we must establish a connection between variety of secondary equipment (including relay protection and automatic device) and primary devices and a variety of equipment. Therefore, the research method based on the GIS platform can be chosen to realize fault analysis better.

GIS platform has realized the integrated management of power network data. When the actual circuit faults occur, the detection of the circuit-breaker state is the basis of the fault diagnosis. In this paper, the circuit-breaker state monitoring terminal of 4G communication module is introduced, and the module sends a command to the monitoring center to identify

the status of the current line when the circuit-breaker is disconnected. The circuit-breaker state is achieving synchronous and real-time display on the GIS platform. Under the premise, the topology of multi power supply circuit is studied, and the simplified topology of the relay protection and circuit-breaker as the key equipment is established. Finally, the line fault location is determined by using the rough set algorithm.

3. Fault diagnosis algorithm of rural power network based on rough set

3.1. The process of fault diagnosis

The fault diagnosis of rural power network can be described as a mode classified problem, and it is quite fit to apply the decision table method of rough set theory. It is the basic idea that we make the movement information of relay protection and circuit breaker as the condition attributes set of fault classification. The decision tables are built for a series fault conditions, and the rough set reduction is applied to reduce the original information to equivalent reduction, and then further reduce the reduction to get the minimum reduction. Finally, diagnosis rules are extracted and the inherent redundancy in the alarm information is exposed. Figure 1 shows the main process of diagnosis.

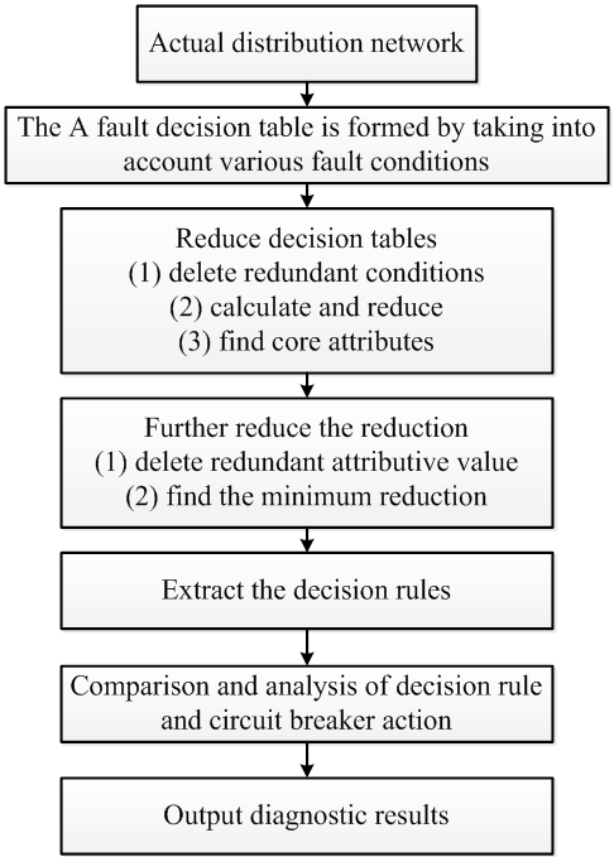

Figure 1. Fault diagnosis flow chart of rural power network based on rough set

3.2. Simulation example

Figure 2 shows a distribution network for test which is the typical form of the metropolitan ring. There are six areas of Sec1, Sec2, Sec3, Sec4, Sec5, and Sec6, furnished with six over current protections C1, C2, C3, C4, C5, and C6. B1, B2 and B3 are feeder switches of substation in the figure. R0 is interconnection switch. R1, R3 and R5 are switches additional feeder switches. R2, R4 and R6 are load segment switchers. These switchers are all permanent-magnet vacuum circuit-breaker that have the opening and cutting short circuit current capability. During normal operation, B1, B2, B3, R1, R2, R3, R4, R5 and R6 are on connect state, R0 is on disconnect state. According to the relay protection operation principle, the decision table is built considering single fault diagnosis [10] and it has 16 samples and 16 conditions, shown in Table 1. In the decision table, "1" denotes the circuit-breaker is opened or protected, and "0" denotes the circuit-breaker is closed or not protected, and "No" denotes there are no faults. Samples 3,6,9,10,11,12,13,14 and 15 are the conditions of vacuum circuit-breaker are non-act.

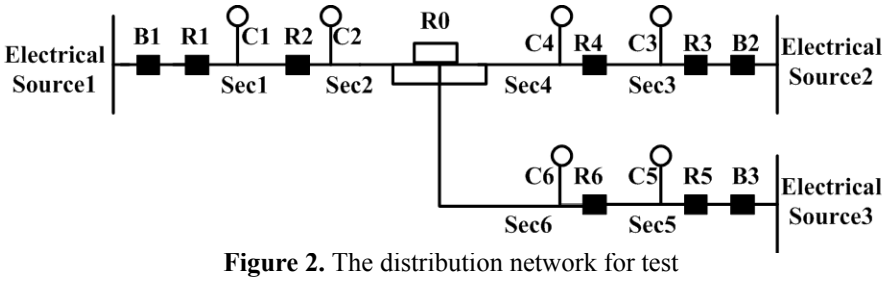

Figure 2. The distribution network for test

Table 1. Decision table of rural power network fault diagnosis

Samples	B1	B2	B3	R0	R1	R2	R3	R4	R5	R6	C1	C2	C3	C4	C5	C6	Fault
1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	Sec1
2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	Sec2
3	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	Sec2
4	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	Sec3
5	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	Sec4
6	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	Sec4
7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	Sec5
8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	Sec6
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	Sec6
10	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	Sec1
11	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	Sec2
12	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	Sec3
13	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	Sec4
14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	Sec5
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	Sec6
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No

The condition attributes set of decision table can obtain the reduction {C1, C2, C3, C4, C5, C6} after calculation. Table 2 shows each important character of the fault. It provides a new thought for treatment of incomplete operating signal, namely, the redundancy of operating information can be used to built different reduction. Keeping away from the lost or inaccurate signal achieves correctly diagnose.

Table 2. The reduction {C1, C2, C3, C4, C5, C6}

Samples	C1	C2	C3	C4	C5	C6	Fault
1	1	0	0	0	0	0	Sec1
2	0	1	0	0	0	0	Sec2
3	1	1	0	0	0	0	Sec2
4	0	0	1	0	0	0	Sec3
5	0	0	0	1	0	0	Sec4
6	0	0	1	1	0	0	Sec4
7	0	0	0	0	1	0	Sec5
8	0	0	0	0	0	1	Sec6
9	0	0	0	0	1	1	Sec6
10	1	0	0	0	0	0	Sec1
11	1	1	0	0	0	0	Sec2
12	0	0	1	0	0	0	Sec3
13	0	0	1	1	0	0	Sec4
14	0	0	0	0	1	0	Sec5
15	0	0	0	0	1	1	Sec6
16	0	0	0	0	0	0	No

It is gained the minimum reduction as table 3 shown from reducing redundancy attribute value of reduction {C1, C2, C3, C4, C5, C6} further. The minimum reduction of decision table shows that the important character of every fault and the ability of fault diagnosis are as same as the former decision table. When there was a fault in certain section of distribution network running normally as Figure 2 shown, it can make fault diagnosis by the seven rules as shown in the table 3. It can be seen the fault diagnosis method based on RS theory is to avoid the transmission error or lost signal in the redundant alarm information collection, and to achieve the purpose of correct diagnosis. The fault tolerance capability of the method of diagnosis is stronger.

Table 3. The minimal reduction of {C1, C2, C3, C4, C5, C6}

Samples	C1	C2	C3	C4	C5	C6	Fault
1	1	0	*	*	*	*	Sec1
2	*	1	*	*	*	*	Sec2
3	*	*	1	0	*	*	Sec3
4	*	*	*	1	*	*	Sec4
5	*	*	*	*	1	0	Sec5
6	*	*	*	*	*	1	Sec6
7	0	0	0	0	0	0	No

Figure 3 shows the interface of fault diagnosis for "The test of distribution network" using VC#, and we designed some faults in order to prove the validity of arithmetic. The simulation result showed the program was correct and feasible.

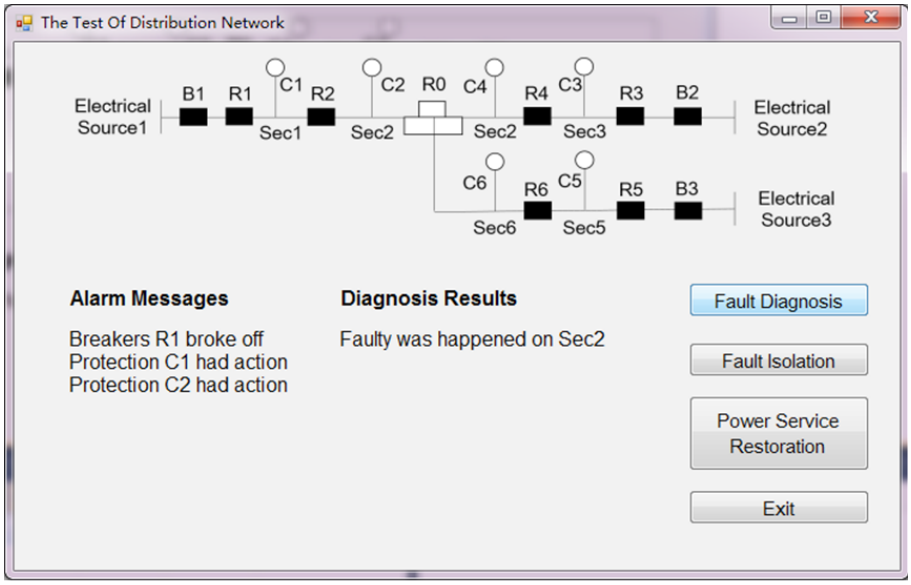

Figure 3. The interface of fault diagnosis for distribution network

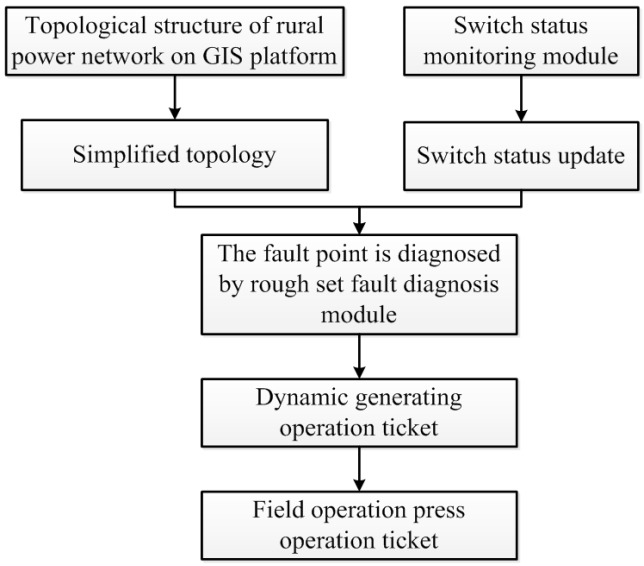

Figure 4. Fault diagnosis flow chart of rural power network based on GIS

4. Fault diagnosis process of rural power network based on GIS

The network management of rural power network based on GIS platform provides the topology of the actual line. A scene simulation environment based on GIS platform is provided about logical connection between the tower, circuit-breaker, and overhead line. When the circuit-breaker on the field line is changed, the circuit-breaker state will transmit in time through 4G communication of monitoring terminal equipment. The fault point location is diagnosed through rough set diagnosis algorithm based on GIS platform, and the system automatically generates the operation order of line scene so that the staffs in accordance with the operation order to achieve the isolation operation of the fault point. Figure 4 shows the specific program flow chart.

5. Conclusions

In this paper, by analyzing the rural power network data of GIS platform, a simplified structure of relay protection and circuit-breaker as key equipment

obtained by reconstruction and simplify. On the basis of the simplified structure, the fault location is determined by using the rough set fault diagnosis algorithm. Finally, the system automatically generates the operation order of the scene of the power network, which can guide the staff to quickly eliminate the fault, shorten the power outage time and improve the reliability of power supply. Combined with the existing 4G communication mode, the circuit-breaker states are quickly detected. The example shows that the fault diagnosis module of the rural power network based on GIS platform and rough set can solve the bottleneck problem of spatial search speed, and the correct diagnosis is achieved by avoiding the transmission error or missing signal in the redundant alarm information. Practical engineering application shows that the search speed and accuracy of fault diagnosis are improved.

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